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Perception of Natural Hazards in Rural Areas: A Case Study Examination of the Influence of Seasonal Weather

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Abstract: A series of factors affect the social perception of hazards in a rural context. This article analyzes how weather conditions influence farmers' perceptions of natural hazards. In order to understand the relationship between time of year/season and farmers' concerns about hazards, this study was undertaken. The methodology was based on surveys done to obtain a base-collection of primary data, as well as a meteorological and production analysis using secondary data. A case study of small coffee farms was carried out in a Brazilian municipality with questionnaires applied during the dry season in 2016 and the rainy season in 2017. The results indicate that drought is the main hazard identified by farmers in both weather seasons. Although there were some changes in perceptions observed, the ranking order of the main hazards did not change over the dry and rainy weather seasons.

Keywords: extreme climate event; hazard; perception

1. Introduction

Contemporary climate change is increasing the risk of extreme weather events like droughts, floods, and extreme temperatures, which pose a bigger threat to those in rural areas. Most of the recent research on vulnerability has been focused on urban areas and less on the rural context, especially in developing countries [1]. Associated with this, social scientific inquiry into environmental hazards is, in relative terms, a recently developing field [2].

According to the Food and Agriculture Organization (FAO) of the United Nations, the agriculture sector is vulnerable and exposed to weather and climate extremes [3]. In developing countries like Brazil, 26% of total losses attributed to natural disasters are accrued in the agricultural sectors. Agriculture absorbs 83% of all damage and losses caused by drought, with 49% of the damage and losses affecting crops. Given the increased occurrence of extreme events, it is important for farmers to recognize the risks of climate change in order for them to adopt appropriate planning and innovative techniques that can be used to reduce vulnerabilities and build resilience [4]. At the same time, the agricultural sector is also a major contributor to global greenhouse gas emissions. These emissions further drive climate change, resulting in an increased occurrence of extreme weather events [5]. Out of the total amount of emissions (CO_{2e}) from Brazil during 2016–2017, 25% comes from the agriculture sector (including emissions from crops, livestock, and soil management) [6].

Climate change is expected to worsen the frequency, intensity, and impacts of some types of extreme weather events, and has already affected food security due to global warming [7]. Though the concepts of climate and weather are closely related, they are not the same. Weather is the mix of events that happen each day in our atmosphere, while the climate describes weather conditions over a 30-year period in a specific area [8]. Extreme weather events are relatively short-term phenomena, while extreme climate events are longer-lived and/or serial phenomena [9].

A natural disaster is an unexpected and/or uncontrollable natural event of an unusual magnitude that can threaten people [6–10]. The study of the perception of hazards, originating in psychology, is based on an attempt to understand the mental processes of an individual's interactions with the environment as they occur using perceptual and cognitive mechanisms [11,12]. Considering the influence that affection, emotion, and stigma has on the perception of risk [13], risk perception studies are defined as an "intuitive judgment of individuals and groups in risk", in contrast to the awareness of scientific knowledge, procedural knowledge, and a rationalization of the perception of human behavior adapted to risk. Risk perception studies provide data that is relevant for the development of policies of mitigation and adaptation to climate change, since these studies focus on the relationship between how individuals perceive risk and how they respond to that risk [12,13]. Risk perception is a subjective judgment that people make about the characteristics and severity of a risk, including their evaluations of the probability, as well as the consequences, of an uncertain outcome [14].

Local weather influences the feelings of an individual, which may affect their personal judgments [13]. Social perception research in different countries suggests that real and perceived periods of high temperature increase people's awareness of climate change [15], while risk perception is sometimes measured by the means of judgments about worrying [16]. It is important to mention that a series of variables influence social perceptions of extreme weather events like previous experiences, and geographical locations; gender does not play an important role in these perceptions in Brazil [17].

Being aware of a risk does not always reflect social attitudes, meaning it is important to understand how social context and the proprieties of the hazards construe how risks are perceived [18]. The objective of this study is to analyze how weather conditions influence the social perceptions of extreme weather events in rural areas such as coffee plantations in Brazil. In addition, we aimed to determine the main natural hazards that affect the study area. The hypothesis of this study is that seasonal weather changes the perceptions of natural hazards occurring in rural areas. It is also important to mention the limitations of this study being solely focused on family farmed coffee plantations, and being restricted to a single city with a sample size limited to a number of questionnaires over a two-year period.

Climate Change and Vulnerability: Impacts on Small Farmers

Agriculture is a sector that involves risk in multiple ways, including production risks (through climatic/weather and/or biological factors) and financial risks (due to price variations, political instability, and business management problems). Extreme climate events have substantial impacts on agriculture [19]. These impacts include the crops, soil, livestock, and destruction of productive infrastructure. Populations associated with small farms or subsistence farming have greater vulnerability to climate change [20]. The frequency and severity of extreme events has increased, and is projected to continue doing so. At the same time, the world's population is expected to grow to 9.7 billion by 2050, which might increase the overall global consumption of food [21,22].

The rise in temperature due to global warming could provoke seed crop losses of R$ 7.4 billion in 2020 and up to R$ 14 billion in 2070, limiting the cultivation area of some crops and generating drastic changes to the Brazilian agricultural production map [18]. For example, coffea arabica is likely to lose up to 33% of its low-risk areas in São Paulo and Minas Gerais by 2070, based on the more pessimistic outlook A2 scenario from the Intergovernmental Panel on Climate Change (IPCC).

There are a multitude of definitions and guidelines on the concept of vulnerability. The definitions for the concept of vulnerability are explained by the diversity of epistemological orientations and methodological practices underlying the concept's operationalization, as well as variations related to the hazards involved (e.g., drought) and the regions under analysis [23,24]. Vulnerability involves the conditions determined by physical, social, economic, and environmental factors or processes that increase the susceptibility of impacts from hazards on an individual, community, assets, or systems [25]. Vulnerability is the degree to which a system is susceptible to, and unable to cope with, the adverse effects of climate change, including its variability and extremes; it is a function of the character, magnitude, and rate of climate change, as well as the variation to which a system is exposed, its sensitivity, and its capacity for adaptation [26].

Pelling (2003) defines vulnerability as the exposure to risk and an inability to avoid or absorb potential harm [27]. In this context, it is possible to categorize vulnerability into three main groups: physical vulnerability, which is the vulnerability of the physical environment; social vulnerability, which is experienced by people and their social, economic, and political systems; and human vulnerability, which is the combination of physical and social vulnerability. In this sense, aside from the natural phenomena and the local social characteristics, the capacity of humankind's resistance and their ability to overcome hazards is increasingly the focus of studies and actions.

Territorial vulnerability due to the inability to deal with adverse events can compromise the resource base of the rural population, thus impeding sustainability in the medium-term and long-term [28]. This context particularly affects family farms, whose vulnerable situation weakens their resource base as well as the sustainability of the overall system [28]. In this way, property and work are closely linked to the family. The definition is not unanimous, but the concept of family structured agriculture has three basic attributes: management, property, and family work [29]. How production is organized in the case of small farmers considers, in addition to the relationship of production and economic profitability, the objective needs of the family [30].

Vulnerability is defined in the Hyogo Framework for Action as the conditions determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards [31]. Vulnerability is used to reveal situations involving exposure to a specific group of people [32]. In this sense, rural areas are a group that is vulnerable to natural hazards, with rural women being particularly susceptible [33].

Extreme weather events challenge the infrastructure, economy, and in part the livelihoods in agricultural areas. In recent decades, an increase of such events has been observed in Brazil. Society and politics need to address these risks and increase awareness and strategies towards resilience. In this context, strengthening the resilience and adaptive capacity of small farms supports the Sustainable Development Goals (SDGs) that are designed to achieve a better and more sustainable future [34]

2. Materials and Methods

The intent of this study is to examine the weather's influence on the social perception of natural hazard risks in rural areas. This study adopted mixed method procedures, supporting the data collection and the decision of collection sampling [34,35]. The methods used in this study involved collecting quantitative secondary data first and then qualitative primary data of coffee growers' perceptions of risk in two weather seasons (Figure 1). Secondary data was collected from official institutes regarding meteorology, productivity of coffee plants, and prices of coffee. Primary data was obtained through surveys based on closed and open-ended questions applied during the dry season in 2016 and during the rainy season in 2017. The qualitative data used printed questionnaires applied in locu, measuring the ranking order of natural hazards that rural producers were primarily concerned about. Questionnaires are a popular and fundamental tool for acquiring information on public knowledge and the perception of natural hazards [36,37].

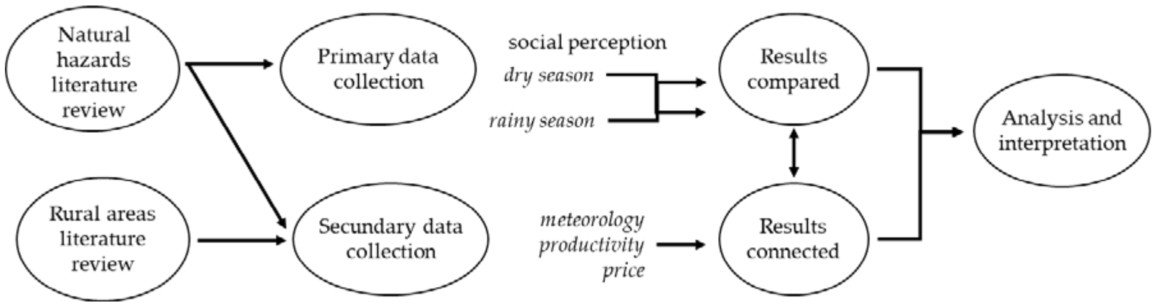

Figure 1. Research model aspects adopted in the study.

Conducting fieldwork with the surveys in rural areas faces some key obstacles, like longer distances to overcome, difficulties accessing the residents of rural areas, resistance of residents in giving information on first contact, and the lack of existence or instability of telephone signals. Commonly, the rural area of Brazil has unpaved roads and hard-to-reach places. A population-based study requires, besides the knowledge of the location, a series of strategies to reach the households and locate the residences with individuals within the properties [38]. This might explain why most of the studies about climate risks in Brazil are focused on urban spaces [39].

Primary Data Collection in a Dry and Rainy Season

A focus group discussion with four participants, members of the Agricultural Association Barra Grande Caconde (AABGC), was used to investigate the experiences and topics of interest in the local context in 2016. The importance of the weather issue for coffee producers in the Caconde region also demonstrated the necessity of shortening the survey to a single page with only a few questions.

In order to evaluate the influence that weather has on farmers' perceptions of natural hazards during the dry season (July, 2016 with a sample size of 39 respondents) and the rainy season (January, 2017 with a sample size of 50 respondents), the questionnaires were applied directly when visiting 60 farms. The AABGC have around 120 rural associated farms, and the response rate was 65% in the dry season and 83% in the rainy season. For the analysis of the primary data sample size, with a population of approximately 1200 coffee farmers, tow confidence intervals were obtained according to the sample size from each season's weather (Table 1).

Table 1. Sample size and confidence interval from each weather season.

Sample Aspects	Dry Season (2016)	Rainy Season (2017)
Confidence level	95%	95%
Sample size	39	50
Population	1200	1200
Percentage	50	50
Margin of error	15.40	13.60

The reason for the varying numbers of survey respondents was the low availability of farmers during the survey in 2016: the interviews were carried out during the harvest and processing period. However, the 2017 survey was carried out during the rainy season, when farmers are usually more available. The surveys were applied using printed questionnaires, administered in situ by AABGC agents during site visits to farmers in 2016 and 2017 in Caconde. Farmers were asked to respond to the survey. The questionnaires were anonymous and the participants from 2016 were not necessarily the same as those from 2017. It is important to emphasize that no extreme weather event occurred in Caconde in the time between the two surveys.

The questionnaires applied in the dry and rainy seasons had one common question regarding natural hazards, in order to compare eventual perception changes: "In relation to your rural productivity, select the phenomena that worries you", followed by a list of 13 proposed natural hazards. The respondents could select more than one answer and could also indicate an additional (non-proposed) answer. The primary data was coded and grouped into more comprehensive categories using a specially designed database. All data was checked for entry errors. A database was set up in OpenOffice Calc (spreadsheet) in which statistical associations could be drawn and graphical representations could be created. A statistical analysis was made to identify significant changes, linking the time of year and the season to concerns about particular hazards. The test for mean difference t-test was conducted to evaluate statistical changes. Finally, the data were studied and compared with climatic patterns of temperature and precipitation based on meteorological data from the study area.

3. Study Area

The impacts of extreme events can be amplified in accordance with the type of crop and if the production systems are not ready to cope. In rural areas with permanent crops, such as coffee production, people interpreted this risk as being damage to the productivity of their farm life, as the coffee plant is dependent on long-term weather conditions and production over a long time period. In this context, one of the main producers of coffee in São Paulo State during 2015–2016 is Caconde, which was chosen based on the importance of its coffee production [40]. The study was conducted in Caconde, a municipality located in the state of São Paulo, Brazil (Figure 2). The region is characterized by a mountainous topography, with altitudes ranging from 860 meters to 1195 meters (Figure 3).

Figure 2. Location of the municipality of Caconde.

Figure 3. Rural area in Caconde (photo taken by the authors in 2016).

According to the 2016 census report, the population is 19,001, with approximately 32% living in rural areas [41,42]. The region is characterized by a tropical altitude climate, with a dry season between June and September of temperatures below 18 °C and with a rainy season between January and March that has temperatures above 22 °C [43]. Caconde is characterized as being a municipality with an economy dependent on rural activity, which specializes in the production of high-quality coffee. According to the Department of Agriculture and Environment of Caconde, there are about 2185 rural properties. Out of these rural properties, 1200 are dedicated to the cultivation of coffee. Family farming is also characteristic of the study area, where 90% of the properties have less than 10 hectares.

4. Results and Analysis

4.1. Secondary Data of Meteorological Data and Extreme Events

Meteorological data from the Caconde station indicate that in 2017, the daily average temperature was 20.5 °C, with annual precipitation of 1706 mm, while in 2016 the daily average temperature was 20.9 °C and there was 2012 mm of precipitation. Between 2011 and 2017, the daily average temperature was 21.1 °C. In 2016, higher precipitation and lower temperatures were observed versus 2017 (Figure 4).

Figure 4. Precipitation (bars) and temperature (lines) data in Caconde [40].

The hazards related to extreme natural phenomena in Caconde, as reported by farmers to the Agricultural Association Barra Grande Caconde (AABGC), include drought, high temperatures, a strong frost in 1994, a weaker frost in 2013, and periodic cases of hail reported every year since approximately 2011. The region of Caconde suffered a historical drought in 2014 [44]. Due to this water crisis, the Caconde dam was left only with the Pardo River base, which was considered as an extreme event in the city (Figure 5). Since the construction of the dam, which began operations in 1966, the stone bases of the houses of the Italians who lived on the site had not been seen (Figure 6).

Figure 5. View of the dam during the 2014 drought in Caconde (photo taken by Neliton de Figueiredo in 2014).

Based on the Brazilian Atlas of Natural Disasters [45], Caconde has recorded one flood; according to the Caconde's Department of Agriculture and Environment, a flood that occurred in 2013 when

125 mm of rain was registered in one hour. The Environment Department of Caconde noted other cases of extreme phenomena, including strong frosts in 1983 and 1994, heavy rains in 2005, and the prolonged drought between 2013 and 2014. The projected impacts of climate change in Caconde, as well as in the states of São Paulo and Minas Gerais, under scenarios A2 and B2 of the IPCC, indicate that, generally, a "low climate risk" is forecasted for 2020, 2050, and 2070 in coffee growing areas [46].

Figure 6. Old houses that emerged during the 2014 drought in Caconde (photo taken by Neliton de Figueiredo in 2014).

4.2. Secondary Data of Coffee Production

Caconde is, economically speaking, strongly dependent on coffee production; out of 2185 rural properties in Caconde, 1200 are devoted to growing coffee, with an average area of 6.5 ha/farm [47]. Between 1990 and 2017, coffee occupied approximately 99% of the agricultural land in the municipality, being its main permanent crop. The coffee yield in Caconde represented a productivity average of 1.29 ton/ha between 1990 and 2017 (Figure 7). There was a large increase in yield in 1997, which is explained by volatility in the market price of coffee, which increased in 1997, with a peak in prices that increased by about 90% compared to previous years.

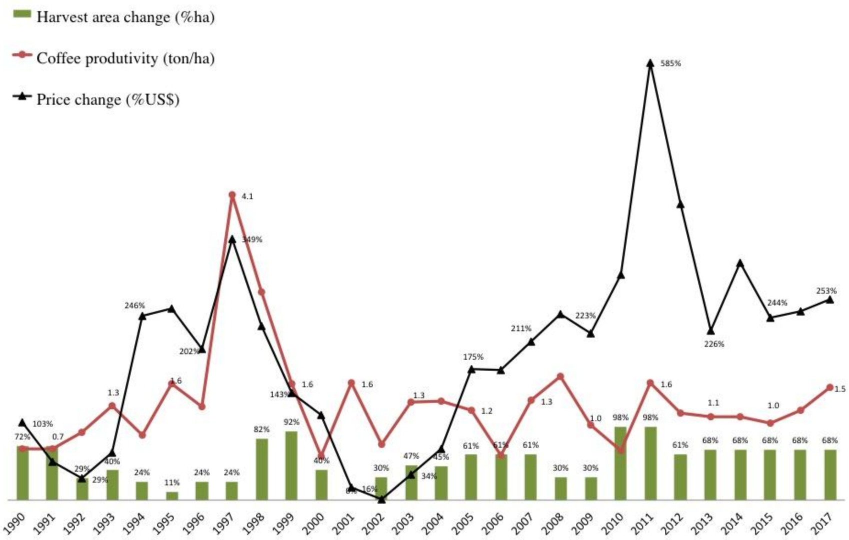

Figure 7. Harvest area change (% ha) cultivation, productivity of coffee (ton/ha) and price variation (% US$) in Caconde between 1990–2017 [47].

4.3. Primary Data from the Survey

In both survey seasons, respondents were typically 31–50 years of age, male, working, and living in Caconde for more than 11 eleven years. Regarding the main cultivated products, coffee takes first place, followed by fruits, vegetables, and maize. Most properties have some type of technical assistance to support cultivation. Considering the 1200 rural properties in Caconde dedicated to the cultivation of coffee, we can consider the sample comparable in Caconde, with an error rate of less than 10%.

Regarding the Agricultural Climate Risk Zoning's research taken from interviewees in the dry season of 2016, most properties (67%) received technical advice; but almost half the respondents (45%) indicate that they did not consult the planting dates of coffee as indicated by the Agricultural Climate Risk Zoning. This has big implications for an integrated policy of risk management in agriculture.

Regarding the weather and agriculture information gathered from the interviewees in the rainy season in 2017, the survey responses indicate that almost all respondents (96%) are usually highly informed about the weather (through communication channels like newsletters, reports, newspapers, magazines, news, or reports). Most respondents (92%) believe that the agriculture sector will be the main sector affected by climate change and 88% of farms do not use irrigation on their property. They also believe the projections of temperature increases made by studies of climate science (100% of the answers). However, 82% of the smallholder respondents are unaware of the initiatives proposed under Brazil's Low-Carbon Agriculture Plan (ABC Plan). The ABC Plan is a national policy, under the scope of the National Plan on Climate Change that seeks to organize and plan sustainable production technologies. It is a credit initiative that provides low-interest loans to farmers who want to implement sustainable agriculture practices. These include no-till agriculture, the restoration of degraded pasture, the planting of commercial forests, biological nitrogen fixation, animal waste treatment, as well as the integration of crops, livestock, and forests. Climate impacts were blamed for 0–20% of economic losses in production over 2016 by 92% of the respondents. Finally, just 16% of the respondents have taken some type of adaptive action because of weather conditions in the last five years, to reduce damage to agriculture production.

4.4. Primary Data of Social Perception of Hazards in Dry and Rainy Season

Responses from the dry season and rainy season indicate that from a list of natural phenomena that cause concern for agricultural production, drought was the most frequently chosen event (Figure 8). The differing values attributed in seasons did not change the three most prevalent natural hazards listed by respondents, nor did the percentage changes of each chosen hazard vary in a predictable way.

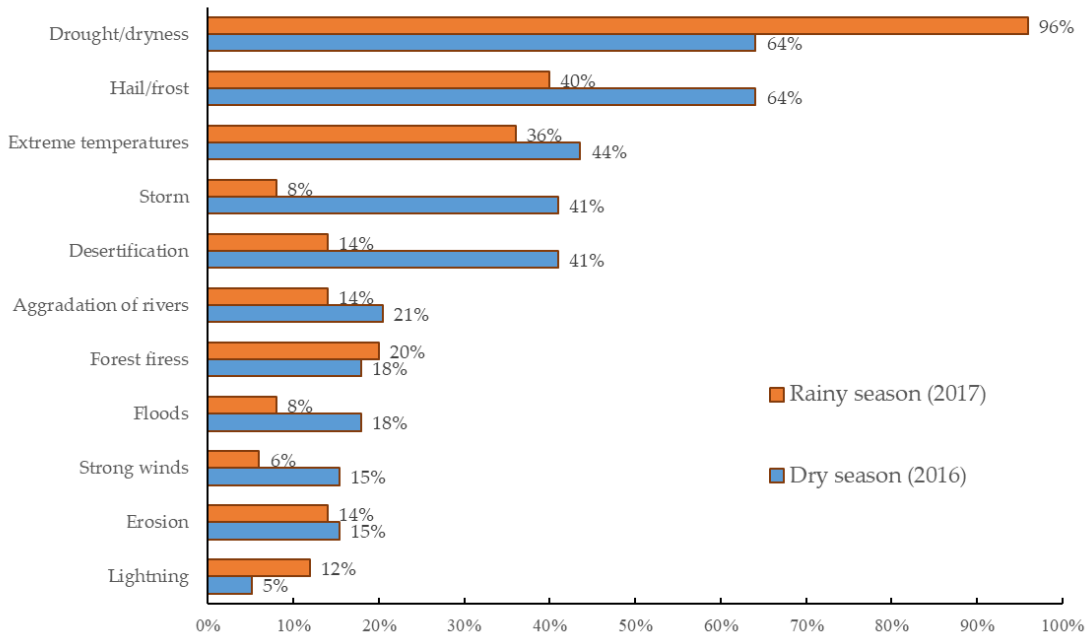

Figure 8. Risk perception of natural phenomena on agricultural yield in a rainy season and a dry season.

The results indicate that the rank order of the main hazards did not change when comparing the dry and rainy season. The results obtained indicate that the perception of extreme events had an average difference of 7% between the two seasons. During in the rainy season 64% of farmers said that they worry about the risk of drought, in the dry season, 96% were worried about the risk of drought.

The general analysis of the statistical t-test for the difference in means results indicated that on average, there is a significant difference between the means of perception the rain and dry seasons (results of the t-test of two sample assuming different variances: hypothesis of mean difference = 0; t-stat = 0.076; P(T <= t) one tail = 0.244; this test of difference was chosen based on the variance analysis). Using the boxplot technique, it was possible to observe the differences between seasons, including the biggest mean perceptions regarding the dry season and the main variation of perceptions on the rainy season (Figure 9).

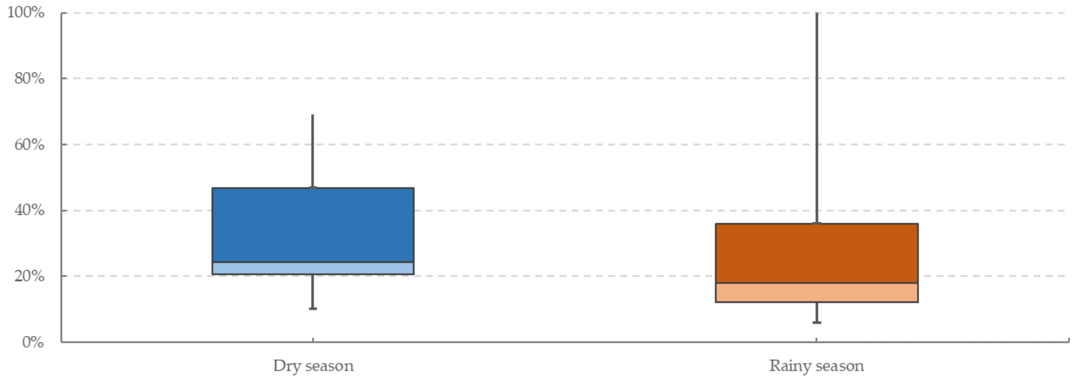

Figure 9. Boxplot showing differences of perception in the two weather seasons.

The detailed analysis, through the difference in the perception of each natural phenomena related to the average between the two weather seasons shows that on average, the perceptions of risk are higher in the dry season (Figure 10).

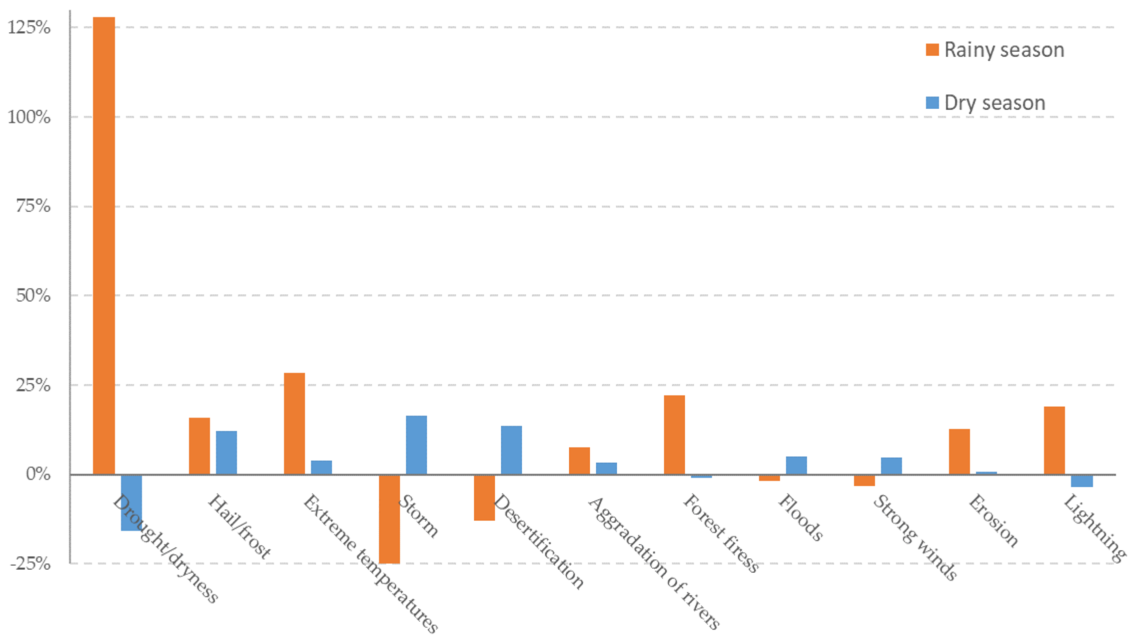

Figure 10. Perception change of each natural phenomenon between the rainy and dry seasons.

5. Conclusions

The study carried out underscores the social perception of natural hazards in rural areas in two different weather seasons. The methodology adopted allowed the authors to conduct an integrated analysis of the findings. The logistical difficulties involving fieldwork in rural areas were identified in Caconde. These situations had repercussions on the survey responses, financial cost, and the time of execution of this study.

The results indicated how the weather conditions influence what farmers perceive to be the biggest risks. The study of coffee farmers conducted to investigate the perception of natural hazards indicated perception as a social memory drawn from real risk, as the example of the drought disaster from 2014 showed. For the two seasons surveyed, drought was indicated as the greatest hazard for most farmers in Caconde's rural area, which is consistent with the FAO study indicating that in developing countries, 83% of all damage and loss caused by drought is faced by agriculture. During the rainy season, the perception of the risk drought was higher than it was during the drought season, while the same relationship was observed when analyzing perceptions of floods. In this study area, rural residents are unaware that early warning systems are available from the Civil Defence and the Agricultural Climate Risk Zoning.

An important aspect of the study of risk perception is to understand what people perceive versus what science can actually measure. The study of social perception makes it possible to verify that, although the Brazilian Atlas of Natural Disasters indicates that floods have occurred in Caconde, it is rarely perceived as a phenomenon requiring concern. Perhaps this limited concern about floods in Caconde is due to its mountainous topography. Extreme events (the 2013 flood and the 2014 drought) did not cause significant changes in the yield area or in coffee productivity. This might be explained by the fact that, due to the risk of frost, coffee is cultivated in higher elevations in areas not exposed to floods. It could also be due to the fact that the 2014 drought did not occur during the critical phases of coffee formation (spring flowering). In 1994, it was observed that there was a reduction of harvest areas and productivity, even though the price had increased; this outcome might be related to the strong frost that was reported. The overview of the results suggests that vulnerability in rural areas is therefore subjective and contextual.

In addition, analyzing the results from the two surveys covering different weather seasons allowed the authors to conclude that an influence of weather seasons on the perception of natural hazards in rural areas exists, which is consistent with the literature (e.g., Andrade et al., 2011). Finally, for the regional context studied, the results show strong evidence of how the weather season changes the perception of main natural hazards. However, this difference does not change the list order of the perception of main natural hazards.

Author Contributions: R.R.R.R. and S.N.S. conceived and designed the research; R.R.R.R. drafted the manuscript and prepared figures and revised the manuscript; M.B., S.S. and M.A.L. discussed the results. All authors have read and agreed to the published version of the manuscript.

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